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TNO-report



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IZF 1990 B-10

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DO INFORMATION SEARCH PATTERNS
REFLECT INTEGRATION RULES?

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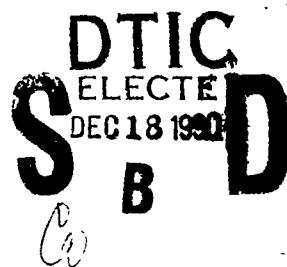
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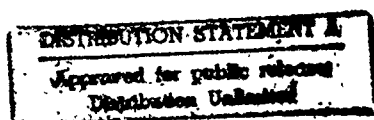
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Number of pages: 19

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Report No.: IZF 1990 B-10

Title: Do information search patterns reflect integration rules?

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TNO Division of National Defence Research
Group: Cognitive Psychology

Date: August 1990

HDO Assignment No.: B87-37

No. in Program of Work: 733.2

SUMMARY

Structural modelling research and studies using information boards have reported contradicting findings regarding the cognitive processes underlying individual decision making. Whereas in the structural modelling approach choices could well be predicted by linear models, information board studies have stressed the nonlinear use of information as a dominant decision strategy.

One explanation for this result addresses the major assumption of the information board paradigm, asserting that decision strategies can be inferred from information search patterns. A major research finding is that information search patterns change with task complexity, i.e. with high task complexity depth of search is decreased, which means that less information is requested, and variability of search is increased. Higher variability of search is directly translated to an increased use of noncompensatory strategies. In the present experiment the agreement between subjects' choices and best choices as calculated by a linear model are compared in two task complexity conditions. It was hypothesized that if information search patterns reflect integration rules agreement between subjects' choices and linear model predictions should decrease with increased task complexity.

The results showed that, even though depth of information search decreased and variability of search increased in the high complexity condition, relative agreement between subjects' choices and linear model predictions remained constant across task conditions.

These results may suggest that information search patterns cannot be directly translated to information integration rules. In particular mechanisms in which knowledge about the task structure is used to infer information not actually stated are discussed.

Geven informatie-zoekpatronen integratieregels weer?

J.H. Kerstholt

SAMENVATTING

Onderzoek binnen het "structural modelling" paradigma en studies waarbij gebruik wordt gemaakt van informatieborden zijn tot tegengestelde conclusies gekomen wat betreft de cognitieve processen die aan individueel beslissingsgedrag ten grondslag liggen. Binnen het "structural modelling" paradigma konden beslissingen goed voorspeld worden met lineaire modellen, terwijl de studies waarbij men gebruik heeft gemaakt van informatieborden benadrukken dat mensen de aangeboden informatie meestal op een nonlineaire manier gebruiken.

Eén verklaring hiervoor is dat de assumptie, die zegt dat beslissingsstrategieën kunnen worden afgeleid van informatiezoekpatronen, niet klopt. Verschillende studies hebben aangetoond dat informatiezoekpatronen variëren met taakcomplexiteit. Als de taak complexer wordt, d.w.z. meer alternatieven of attributen, blijkt dat mensen minder informatie opvragen en de variabiliteit van het informatieopvraaggedrag toeneemt. Toenemende variabiliteit wordt direct vertaald naar een toename van het gebruik van noncompensatoire strategieën. In het experiment dat in dit rapport wordt besproken zijn de keuzes van proefpersonen vergeleken met de beste keuzes volgens een lineair model. Verondersteld werd dat indien informatie-integratieregels kunnen worden afgeleid van informatiezoekpatronen, de overeenkomst tussen de gekozen alternatieven en beste alternatieven volgens het lineaire model af zou moeten nemen als de taakcomplexiteit toeneemt.

Uit de resultaten bleek dat, hoewel de proefpersonen minder informatie opvroegen en de variabiliteit van het informatiezoekpatroon toenam, de overeenkomst tussen daadwerkelijke keuzes en optimale keuzes volgens het lineaire model gelijk bleef over taakcondities.

Deze resultaten zouden er op kunnen wijzen dat informatiezoekpatronen niet direct vertaald kunnen worden naar integratieregels. Met name mechanismen waarbij kennis van de taakstructuur wordt gebruikt om de waarden van niet gepresenteerde informatie af te leiden, worden in de discussie besproken.

1 INTRODUCTION

Process tracing techniques have received growing attention as a means to investigate cognitive processes underlying individual decision making. A fundamental principle of these techniques is that behavioral responses such as eye movements, requested information or verbal statements should be registered as often as possible during the decision process (Svenson, 1979). A popular process tracing technique makes use of information boards with which information search patterns can be determined.

The information board technique requires subjects to choose one piece of information at a time from a matrix consisting of a set of alternatives, usually specified by the columns of the matrix, and a set of attributes which are formed by the rows of the matrix. Both the total amount of information and the order in which individual items are requested is registered and from the specific search pattern the decision strategy is inferred (Billings & Marcus, 1983; Svenson, 1979).

Although various decision strategies have been identified, the two major categories can be described as compensatory and noncompensatory strategies. When subjects use a compensatory strategy, the same amount of information is processed for each alternative and trade-offs reflecting the decision makers' values are incorporated into the decision. This means that a low score on a specific attribute can be compensated by a high score on another attribute. On the other hand, noncompensatory strategies such as an elimination-by-aspects rule do not take trade-offs into account. Instead, such strategies use cut-off points which are well defined criteria below or above which alternatives are rejected or accepted (Billings & Marcus, 1983).

A robust conclusion from various studies using information boards is that choice processes are commonly characterised by a nonlinear combination of information (Ford et al., 1989). Only when the decision task is simple, i.e. few alternatives and/or attributes, compensatory strategies are employed (Olshavsky, 1979; Payne, 1982). Otherwise, people are highly selective in their use of information and use simplifying rules, noncompensatory strategies, that preclude the necessity for complete processing of all relevant information. Yet, whereas process tracing techniques demonstrate the nonlinear use of information, another descriptive research method, structural modelling, indicates the robustness of the linear model for predicting choices made by the decision maker. Just as is the case for compensatory

tory strategies in general, the linear model implies that the decision maker uses a complex averaging process in which a decision reflects a trade-off among conflicting evaluations (Pitz & Sachs, 1983).

Several differences between process tracing techniques and structural modelling may account for these contradicting findings. In the first place, different techniques are used to deduce the cognitive processes underlying actual decisions. Whereas process tracing techniques are based on the registration of behavioral responses during the decision process, in the structural modelling approach the decision process is inferred after the decision is made by relating information input to decision outcome by means of statistical models. Generally, a set of decisions is gathered and with multiple regression the cue-weighting scheme is determined that best accounts for the decisions actually made by the decision maker (Abelson & Levi, 1985).

At a more psychological level it has been suggested that these paradigms differ in response mode and stage of the decision process tapped by the method. First, the structural modelling approach requires a judgment whereas in the information board paradigm a choice response is required (Einhorn, Kleinmuntz & Kleinmuntz, 1979; Billings & Marcus, 1983). In a judgment task each alternative is explicitly evaluated. A choice response, in contrast, requires only that one alternative is selected and the rest rejected. It was indeed shown experimentally that information search pattern varied as a function of response mode (Billings & Scherer, 1988; Westenberg & Koele, 1990).

The second difference between the two paradigms concerns the stage of the decision process that is studied. It has been suggested that the process tracing paradigm is more directed towards the information acquisition phase whereas the structural modelling paradigm concerns the integration of information (Billings & Marcus, 1983).

This last explanation challenges directly a major assumption of the information board technique which is that the information integration phase, or decision strategy, can be inferred from the information search pattern. In other words, it is questioned whether there is a direct correspondence between the way information is requested and the way information is used to form an overall evaluation of the alternatives.

In the information board paradigm the use of a compensatory strategy is inferred when an equal amount of information is requested for each alternative. Variability of search is usually indexed by the standard deviation of requested information units across the set of alternatives. It is inferred that a compensatory strategy is used when the

standard deviation is equal to zero. A standard deviation greater than zero implies that an unequal amount of information is requested for each alternative. In that case it is inferred that subjects eliminated or accepted alternatives after the evaluation of specific attribute values, which means that they have used a noncompensatory strategy. A major variable affecting information search is task complexity. It has been consistently found that as task complexity increases, more alternatives and/or attributes, variability of search increases and relatively less information is requested, i.e. depth of search decreases (Svenson, 1979; Olshavsky, 1979; Ford et al., 1989). This strategy change is explained by limitations of human information processing capacity. It is suggested that as the task becomes too complex to consider the relevant information for all alternatives, as is required for a compensatory strategy, people will turn to less demanding strategies, i.e. noncompensatory ones (e.g. Russo & Doshier, 1983).

In the present experiment we will compare choices with a linear model, which describes the evaluation of a given alternative as a summation of the weighted evaluations of its attributes:

$$U = \sum_j w_j u_j$$

It represents a multi-attribute utility model in that it assumes that the evaluation of a given alternative is obtained by summing the weighted evaluations of its different attributes. Of primary importance in the present experiment is the agreement of actual choices and best choices obtained by the linear model. Several researchers have noted that linear models are not sufficient when one is interested in the processes used in arriving at a decision (Fischhof, Goitein & Shapira, 1983; Pitz & Sachs, 1983). To predict decisions one only has to know the attributes the decision maker considers and predictability is rather unaffected when weights are varied. However, if subjects use simplifying heuristics, a linear model should be expected to yield poorer agreement with actual choices. Garvill et al. (1990) and Lindberg et al. (1989, 1990) have indeed shown that better predictions were obtained for preferences than for choices. They explained this result by stating that choices are more complex than preference ratings in terms of processing demands, which leads people to employ simplifying strategies.

As noted by Johnson and Payne (1985), a limitation of a strict comparison of predicted and actual choices is its insensitivity to near misses, such as the selection of an alternative near the one with the highest overall evaluation. We therefore express agreement between actual choices and predicted linear choices by relating the utility of the chosen alternative to the overall evaluation of the best and the worst option:

$$\text{relative agreement} = \frac{U_{\text{choice}} - U_{\text{min}}}{U_{\text{max}} - U_{\text{min}}}$$

From previous results it is expected that amount of requested information decreases and variability of search increases in more complex task conditions. If this change in information search pattern implies a shift from compensatory to noncompensatory strategies we expect the agreement between linear model predictions and actual choices to decrease with increased task complexity.

2 EXPERIMENT

2.1 Method

Subjects

21 Male subjects participated in the experiment. Their mean age was 18,9 years ($\sigma=1,2$).

Material

The task involved choices between apartments for rent. An apartment could be described on 8 attributes each with three levels: rent (300, 600 or 900 Dutch guilders); size (2, 3 or 4 rooms); location (bad, moderate or good), distance to work (far, reasonable or small), distance to shops (far, reasonable or small), noise level (high, moderate or low), presence of garden or balcony (big, small or absent) and state of repair (good, reasonable or bad). Care was taken to avoid dominant alternatives, that is, alternatives which clearly stand out by having desirable values on all of their attributes.

Procedure

Subjects were asked to imagine that they had to rent a house. An experimental session comprised three tasks. In order to calculate the overall utility of each alternative we needed both the evaluations of

each attribute level and the weights assigned to each attribute. The first and second task served this purpose.

In the first task the subject was given a form on which all value levels of each attribute were listed. The subject was asked to indicate the attractiveness (utility) of each value level on a 7-point scale.

In the second task subjects were given eight charts, on which the eight attributes were written, and they were asked to rankorder the charts in terms of importance. Weights were inferred by assigning a weight of 8 to the most important attribute, 7 to the next important attribute and so on until the least important one got a weight of 1.

The third task required the subject to choose the most preferable apartment from 4 different choice sets by means of computerised information boards. Each column of the board specified a house, whereas the rows indicated attributes. The subjects were required to consider their own actual situation and to request as much information as they needed to make a reasonable choice.

Furthermore, after they had made their choice, the subjects had to indicate how confident they were that they had made the right choice and how difficult they found the choice problem. These scores were given on a 9-point scale.

Design

Both number of alternatives and number of attributes were varied in order to manipulate task complexity. Number of alternatives could either be 3 or 6, and number of attributes could either be 4 or 8. A 'within-subjects' design was used, which means that each subject had to make a choice in each of the complexity conditions. This provides a strong test of adaptivity, since subjects are expected to switch strategies from one decision problem to the next. In order to avoid sequence effects the order of task complexity conditions was balanced across subjects. Furthermore, the combination of attributes in the '4-attributes' condition remained the same for a given subject over task trials, but was varied over subjects. This was done in order to make the 3 and 6 alternative conditions comparable with regard to the attributes on which they were judged.

2.2 Results

As was mentioned in the introduction, results obtained with information boards have consistently shown a decrease in depth of search (less information is requested) and an increase in search variability

with increased task complexity. Table I shows the results of our experiment concerning depth of search (indexed by the proportion of requested information) as a function of task complexity.

Table I Proportion of information that was requested in each task complexity condition.

number of <i>attributes</i>	number of <i>alternatives</i>	
	3	6
4	0.75	0.63
8	0.63	0.47

An analysis of variance with two within subjects factors (number of alternatives and number of attributes) was carried out over the proportion of information that was used in each complexity condition. Both number of alternatives and number of attributes had a significant effect on the proportion of requested information ($F(1,20)=31.1$; $p<0.001$ and $F(1,20)=27.9$; $p<0.001$). The interaction was not significant ($F(1,20)<1$). These results imply that a smaller proportion of information was used as complexity increased.

Table II shows the variability of search, indexed by the mean standard deviation of requested information units across alternatives, as a function of task complexity. Note that within the information board paradigm variability of search is directly translated to the kind of strategy that is used, i.e. a standard deviation of zero means that a compensatory strategy was employed.

Table II Mean standard deviation over alternatives for requested information as a function of task complexity.

number of <i>attributes</i>	number of <i>alternatives</i>	
	3	6
4	0.76	0.90
8	1.67	1.73

Analysis of variance showed that only number of attributes had a significant effect on the variability of search ($F(1,20)=52.9$;

$p < 0.0001$). An increase in number of alternatives had no effect on search variability ($F(1,20) < 1$). The same pattern was found for the subjective evaluation of task complexity. Table III shows the mean scores.

Table III Mean scores of subjective difficulty judgments for each task complexity condition (on a 9-point scale).

number of attributes	number of alternatives	
	3	6
4	3.5	2.9
8	4.6	4.7

Only number of attributes produced a significant effect ($F(1,20) = 9.4$; $p < 0.01$). The F-values for alternatives and interaction were respectively 0.4 and 0.9.

These results indicate that our manipulation of task complexity affected both the proportion of information that was requested and the variability of search, even though this last effect only held for number of attributes. Furthermore, subjects evaluated the task as more difficult as number of attributes increased. The results therefore clearly replicate the findings from previous studies.

In order to specify the best choices as calculated by a linear model, utilities were calculated for all alternatives and for each subject. The utilities for each attribute level were expressed by the attractiveness scores as measured by the questionnaire and to get the overall evaluation of the alternative these scores were weighted and summed. The weights were inferred from the rankorder of the 8 attributes. A weight of 8 was assigned to the most important attribute, a weight of 7 to the next important one and so on until the least important one got a weight of 1. The best choice was the house with the highest utility in the set of alternatives. Multi-attribute utility was based on all information that could have been requested.

Table IV shows the relative agreement between subjects' choices and alternatives with the highest utility for each task complexity condition. As was mentioned agreement is calculated by the following formula:

$$\text{relative agreement} = \frac{U_{\text{choice}} - U_{\text{min}}}{U_{\text{max}} - U_{\text{min}}}$$

A score of 1 implies that the alternative with the highest overall utility was chosen and a score of 0 that the alternative with the lowest utility was selected.

Table IV Relative agreement between subjects' choices and alternatives with the highest utility as calculated by a linear model.

number of attributes	number of alternatives	
	3	6
4	0.75	0.89
8	0.67	0.83

For both number of attributes and number of alternatives no significant effect was found ($F(1,20) < 1$ and $F(1,20) = 1.69$; $p > 0.2$ respectively). In order to indicate the influence of the weights that were used, we have also calculated the relative agreement scores when the overall evaluation of the alternatives are expressed by a summation of unweighted utilities. These scores are shown in Table V.

Table V Relative agreement between subjects' choices and alternatives with the highest unweighted utility as calculated by a linear model.

number of attributes	number of alternatives	
	3	6
4	0.73	0.84
8	0.69	0.78

Again no effects were found for both number of alternatives and number of attributes ($F(1,20) = 1.11$; $p < 0.3$ and $F(1,20) < 1$ respectively). Therefore, even though information search patterns changed as a function of task complexity, choices in each task complexity condition agreed moderately well with linear model predictions.

Table VI shows the mean confidence scores, indicating subjects' belief that their choices were correct, for each complexity condition.

Table VI Mean scores of subjective confidence judgments for each task complexity condition (on a 9-point scale).

number of <i>attributes</i>	number of <i>alternatives</i>	
	3	6
4	7.5	7.5
8	7.3	7.2

As expected, the results from a repeated measurements analysis indicated that none of the means significantly differed from each other ($F(1,20) < 1$ and $F(1,20) = 1.11$; $p > 0.3$) for number of alternatives and attributes respectively). Even though less information was requested in the more complex task conditions subjects were equally confident about the correctness of their choice in all complexity conditions.

3 DISCUSSION

The results showed a clear replication of the results reported in the literature. With increased task complexity depth of information search decreased, subjects requested relatively less information, and the variability of search increased. Within the information board paradigm, this result would have been translated to the conclusion that subjects changed from compensatory to noncompensatory strategies as task complexity increased. However, in that case we would have predicted decreased agreement with the outcomes of a linear model and this effect was in the present experiment not observed. Furthermore, subjects were equally confident about their choices in each task complexity condition.

These results may suggest that integration rules cannot directly be inferred from information search patterns, which would challenge the assumption underlying the information board technique. Several cognitive mechanisms can mediate the information search phase and information integration phase. In the following paragraphs three possible explanations for the present findings will be discussed.

First, one does not know whether all of the requested information is actually used by the subjects to produce an overall evaluation of each alternative. In terms of our results this would mean that the agreement between actual choices and predicted linear choices is decreased in the simple task condition because of an incorrect information integration process. Or in other words, even though subjects requested a relatively large amount of information and showed low variability in search when task complexity was low, they did not use all requested information or combined the information linearly.

One of the reasons that people continue requesting information after a tentative choice has been made, is to justify this choice. Montgomery (1989) refers to such a process as a search for a dominance structure, i.e. a cognitive structure in which one alternative can be seen as dominant over the others. In his view, decision processes should be seen as a search for good arguments and not only as governed by a number of decision rules (Montgomery, 1989).

A second explanation against the assumption implied by the information board technique is that subjects can use more information than they have requested. Recently, several studies have been directed towards the way inferences may affect people's preferences (Huber, 1983; Johnson, 1987; Levin, Johnson & Faraone, 1984). If people use knowledge about intercorrelations between variables, make inferences concerning the values of variables not presently shown, the information integration rule that is used is not the same decision rule as the one inferred from the information search pattern. Phelps and Shanteau (1978) for example, showed that expert judges could be modelled with relatively few attributes. As often noted, experts base their decisions on information chunks, making use of correlations between attributes, rather than the explicit weighting of all individual dimensions. The same result is reported in consumer research. Bettman and Park (1980) for example, found a curvi-linear relation between prior knowledge and experience and processing of available information. Consumers with moderate knowledge about the product did more information processing than did the high or low groups. Consumers with knowledge about the product can use brand names as information chunks, decreasing the need to request additional information. The zero-correlation between confidence level and amount of information could also be explained with this viewpoint. Levin et al. (1988) examined the issue of how missing information affected subjects' confidence in their judgments. They observed that confidence ratings were not affected by incomplete information. It was suggested that

this was achieved by high confidence in the inferences made about the missing information.

A third explanation concerns the interactive use of information when subjects work with information boards. During the decision process subjects may conclude from the information requested thus far that the overall score for that particular alternative cannot be compensated and therefore stop to consider the rest of the information. The search patterns can be noncompensatory, but the outcome may well be predicted by linear models. As noted, prediction of outcomes do not guarantee insights into underlying decision processes (Pitz & Sachs, 1983). According to the mechanisms discussed above knowledge of the task structure might explain some of the findings.

Decision research has mostly been directed towards explaining contingent decision behaviour with respect to information capacity limitations. An accuracy-effort model has been regarded as a suitable framework to explain these effects (Russo & Doshier, 1983; Smith, Mitchell & Beach, 1982). In this view, people possess various decision strategies which are selected as a function of the requirements of the task. However, people may well seek to develop strategies that take advantage of the problem structure (Klein, 1983; Payne, Bettman & Johnson, 1988). Rather than a forced switch to less accurate processes because of cognitive limitations people may try to use strategies that require less working memory capacity without a significant drop in accuracy. With increased task complexity, information processing could change from a strict bottom-up integration of information, as is assumed in the information board paradigm, to top-down processing allowing knowledge about the task structure to play a part in the overall evaluation of the options. Recently, the accuracy of various heuristics have been considered, suggesting that some heuristics approximate the accuracy of normative rules quite well (Payne, Bettman & Johnson, 1988). In addition, people appeared to be highly adaptive in responding with different strategies to changes in the structure of presented alternatives and time pressure. In general, actual behaviour corresponded to the general patterns of efficient processing as was identified by simulations of various strategies (Payne, Bettman & Johnson, 1988). In a more natural task setting Faquette and Kida (1988) instructed professionals to employ different strategies to evaluate financial data in order to select firms with the highest bond ratings. Decision performance was measured at three levels of task complexity. The results indicated that an increase in task complexity did not result in a differential decrease in accuracy for complex,

compensatory strategies and simplifying rules such as EBA. In fact, with increased task complexity noncompensatory strategies required significantly less time without reduced accuracy as compared to compensatory strategies.

Results concerning the trade-off between accuracy and effort in strategy selection suggest a fruitful research area regarding the influence of knowledge of the task structure on task performance. This would broaden the view of people as adaptive decision makers, in the sense that both bottom-up integration of information and top-down processing would be incorporated as cognitive mechanisms involved in decision making.

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Soesterberg, August 23, 1990



Drs. J.H. Kerstholt

REPORT DOCUMENTATION PAGE		
1. DEFENCE REPORT NUMBER (MOD-NL) TD 90-1619	2. RECIPIENT'S ACCESSION NUMBER	3. PERFORMING ORGANIZATION REPORT NUMBER IZF 1990 B-10
4. PROJECT/TASK/WORK UNIT NO. 733.2	5. CONTRACT NUMBER B87-37	6. REPORT DATE August 23, 1990
7. NUMBER OF PAGES 19	8. NUMBER OF REFERENCES 27	9. TYPE OF REPORT AND DATES COVERED Final
10. TITLE AND SUBTITLE Do information search patterns reflect integration rules?		
11. AUTHOR(S) J.H. Kerstholt		
12. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) TNO Institute for Perception Kampweg 5 3769 DE SOESTERBERG		
13. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) TNO Division of National Defence Research Koningin Marialaan 21 2595 GA DEN HAAG		
14. SUPPLEMENTARY NOTES		
15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE) <p>Structural modelling research and studies using information boards have reported contradicting findings regarding the cognitive processes underlying individual decision making. Whereas in the structural modelling approach choices could well be predicted by linear models, information board studies have stressed the nonlinear use of information as a dominant decision strategy.</p> <p>One explanation for this result addresses the major assumption of the information board paradigm, asserting that decision strategies can be inferred from information search patterns. A major research finding is that information search patterns change with task complexity, i.e. with high task complexity depth of search is decreased, which means that less information is requested, and variability of search is increased. Higher variability of search is directly translated to an increased use of noncompensatory strategies. In the present experiment the agreement between subjects' choices and best choices as calculated by a linear model are compared in two task complexity conditions. It was hypothesized that if information search patterns reflect integration rules agreement between subjects' choices and linear model predictions should decrease with increased task complexity.</p> <p>The results showed that, even though depth of information search decreased and variability of search increased in the high complexity condition, relative agreement between subjects' choices and linear model predictions remained constant across task conditions.</p> <p>These results may suggest that information search patterns cannot be directly translated to information integration rules. In particular mechanisms in which knowledge about the task structure is used to infer information not actually stated are discussed.</p> <p><i>Keywords: Netherlands, (Kerstholt)</i></p>		
16. DESCRIPTORS Decision Making Task Complexity		IDENTIFIERS
17a. SECURITY CLASSIFICATION (OF REPORT) -	17b. SECURITY CLASSIFICATION (OF PAGE) -	17c. SECURITY CLASSIFICATION (OF ABSTRACT) -
18. DISTRIBUTION/AVAILABILITY STATEMENT Unlimited availability		17d. SECURITY CLASSIFICATION (OF FILES) -

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